Raw waveform fitting: changes to the event display

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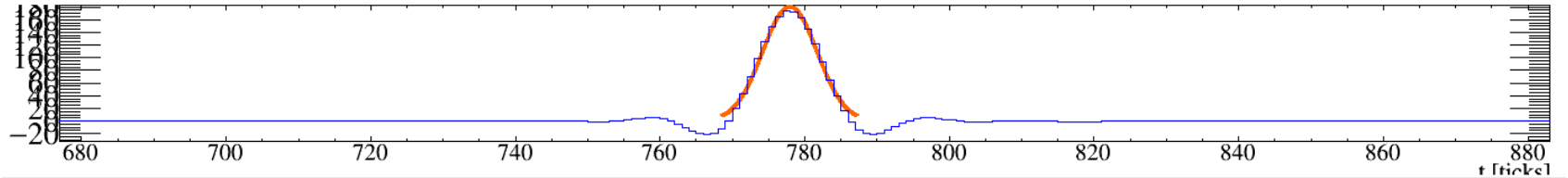
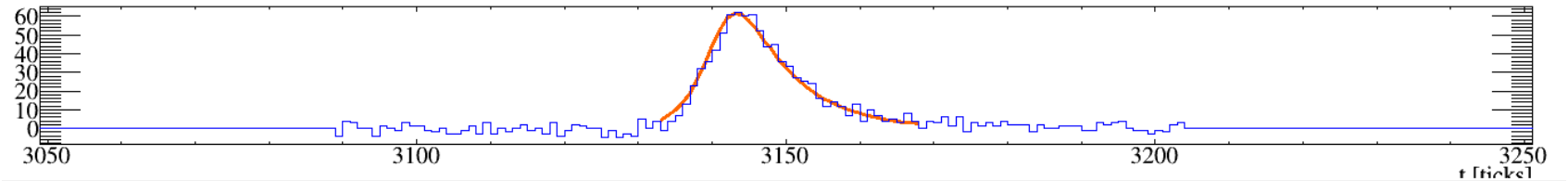
Motivation and overview

Current status: Event display draws Gaussian fits on deconvoluted waveforms



Goal: Add option to draw double exponential fit on raw waveforms for dual phase

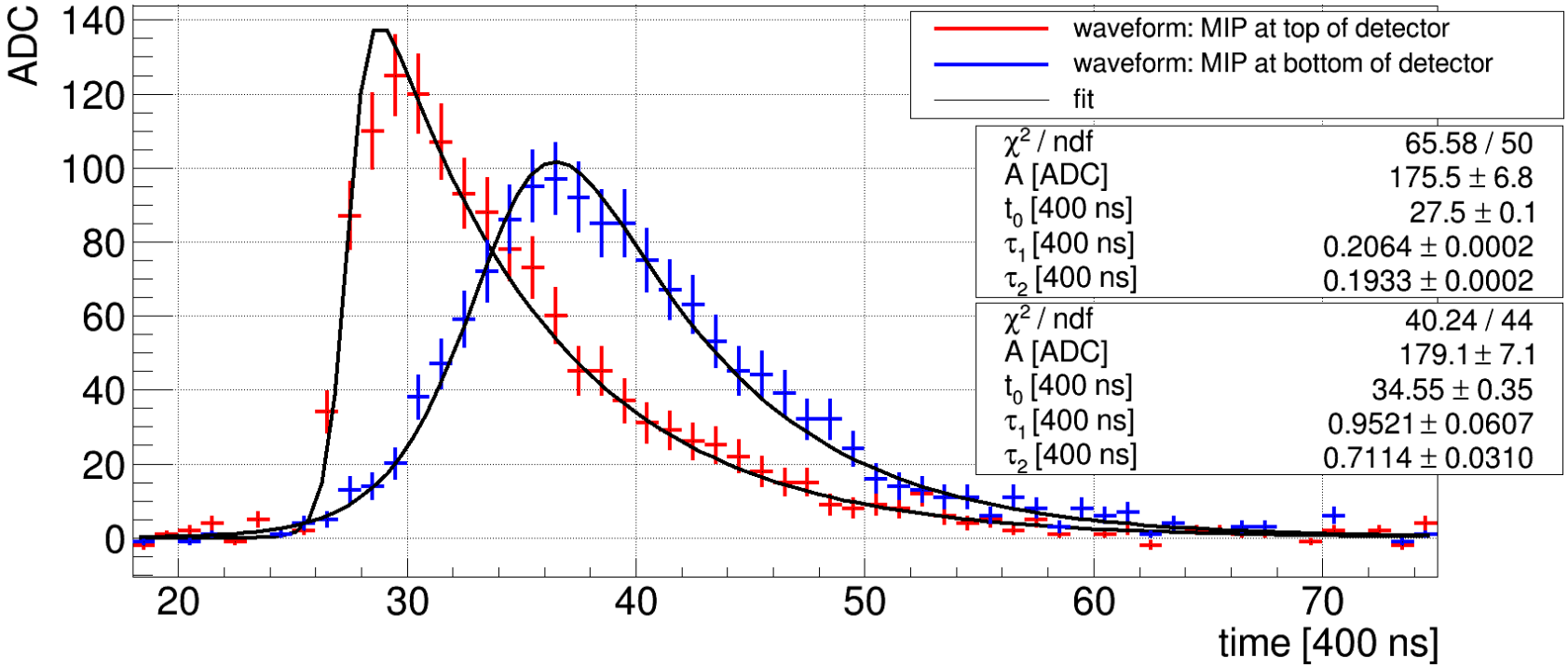
$\rightarrow$ some code changes are needed



Content:

1. Raw waveform fitting
2. MVAWriter/Reader: saving fit parameters
3. Proposed changes in the event display code

Raw waveform fitting (protoDUNE-DP)

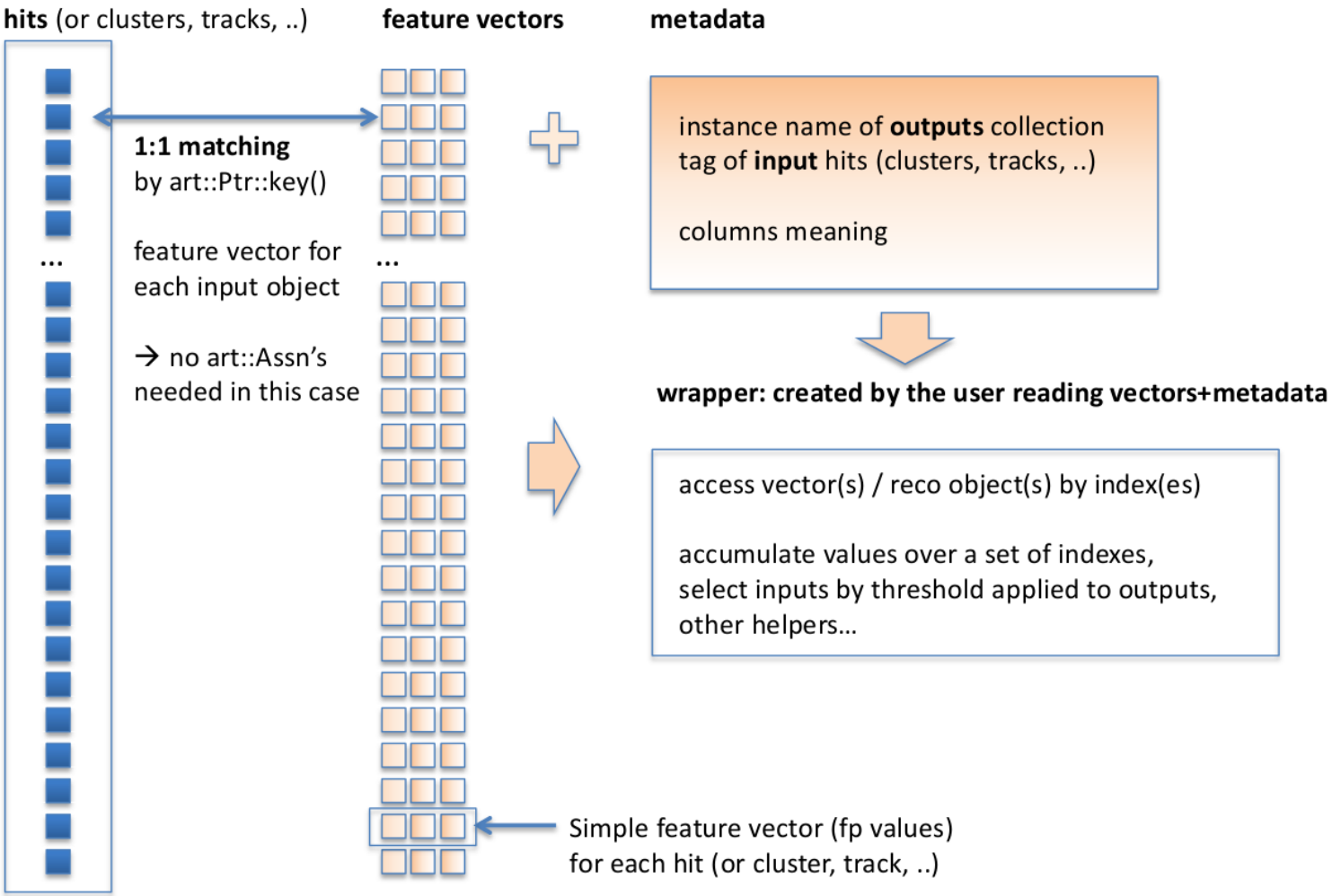


- Fit identified peaks with: $f(t) = A \cdot \frac{e^{\frac{t-t_0}{\tau_1}}}{1+e^{\frac{t-t_0}{\tau_2}}}$
- 4 parameters: t_0, A, τ_1 and τ_2

$\rightarrow$ save fit parameter in feature vectors (MVAWriter)

- Saved parameters only needed for event display (not for reco/analysis)

MVAWriter/Reader by Robert Sulej



Credits: Robert Sulej

MVAWriter: saving fit parameters

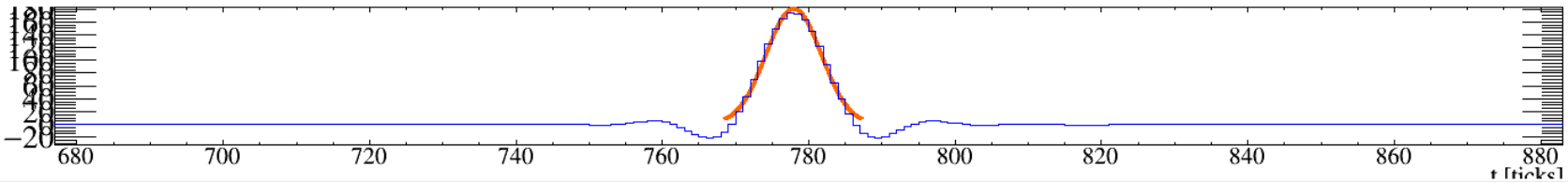
In hit finder/fitter code:

```
#include "lardata/ArtDataHelper/MVAWriter.h"
.
.
// Initialising parameter writer
anab::FVectorWriter<3> fHitParamWriter;
.
.
// declare that data products with feature vectors describing hits are going to be produced
fHitParamWriter.produces_using< recob::Hit >();
.
.
EventLoop
{
        // start collection of fit parameters, initialize metadata describing it
        auto hitID = fHitParamWriter.initOutputs<recob::Hit>(fNewHitsTag, { "t0", "tau1", "tau2" });
        .
        .
        WireLoop
                {
                .
                .
                // add fit parameters associated to the hit just pushed to the collection
                std::array<float, 3> fitParams;
                fitParams[0] = peakMean+roiFirstBinTick; //mean
                fitParams[1] = paramVec[4*hitIdx+2].first; //tau_1
                fitParams[2] = paramVec[4*hitIdx+3].first; //tau_2
                fHitParamWriter.addVector(hitID, fitParams);
        }//WireLoop
fHitParamWriter.saveOutputs(evt);
}//EventLoop
```

Event display: TQPad.cxx

TQPad.cxx now:

1. Get event
2. Read waveform histo and Gaussian fit parameter for spec. wire
3. Draw waveform histo and Gaussian fit for this spec. wire



TQPad.cxx proposed changes:

1. Get event
2. Read feature vectors with double exponential fit parameters for this event
3. if(feature vectors): read and draw waveform histo and double exponential fit for spec. wire
4. else: read and draw waveform histo and Gaussian fit (same as above) for spec. wire

Event display: proposed changes in TQPad.cxx

```
#include "lardata/ArtDataHelper/MVAReader.h"
.
.
const art::Event* evt = evdb::EventHolder::Instance()->GetEvent();
if(!evt) return;

//check if raw (dual phase) or deconvoluted (single phase) waveform was fitted
auto hitResults = anab::FVectorReader<recob::Hit, 3>::create(*evt, "dprawhit");

if(hitResults) //raw waveform (dual phase)
{
        .
        .
        //Fill RecoHisto and get double exponential fit parameters
        this->RecoBaseDraw()->FillTQHistoDP(*evt,
                                            fPlane,
                                            fWire,
                                            fRecoHisto,
                                            htau1,
                                            htau2,
                                            hamplitudes,
                                            hpeaktimes,
                                            hstartT,
                                            hendT,
                                            hNMultiHit);
        .
        .
        //Draw TPolyLine based on double exponential fit
}

else //deconvoluted waveform (single phase)
{
        //Fill RecoHisto and get Gaussian fit parameters
        this->RecoBaseDraw()->FillTQHisto(*evt,
                                          fPlane,
                                          fWire,
                                          fRecoHisto,
                                          hstart,
                                          hend,
                                          hamplitudes,
                                          hpeaktimes);

        .
        .
        //Draw TPolyLine based on Gaussian fit
}
```

Event display: RecoBaseDrawer.cxx

RecoBaseDrawer.cxx now:

- Function RecoBaseDraw(): fills waveform histo, reads Gaussian fit parameter from recob::Hit and returns it to TQPad.cxx

RecoBaseDrawer.cxx proposed changes:

- Add function RecoBaseDrawDP(): fills waveform histo, reads double exponential fit parameter with MVAReader and returns it to TQPad.cxx
- Add function CountHits(): Hit numbering in the event display starts from 0 for each plane. Need the number of hits in all cryostats, TPC's and planes before actual plane to get assignment between the "feature vector" and the "hit" right.

Event display: proposed changes in RecoBaseDrawer.cxx

```
#include "lardata/ArtDataHelper/MVAReader.h"
.
.
void RecoBaseDrawer::FillTQHistoDP(const art::Event&    evt,
                                   unsigned int         plane,
                                   unsigned int         wire,
                                   TH1F*                histo,
                                   std::vector<double>& htau1,
                                   std::vector<double>& htau2,
                                   std::vector<double>& hitamplitudes,
                                   std::vector<double>& hpeaktimes,
                                   std::vector<int>& hstartT,
                                   std::vector<int>& hendT,
                                   std::vector<int>& hNMultiHit)
{
.
.
//Reading double exponential fit parameters
auto hitResults = anab::FVectorReader<recob::Hit, 3>::create(evt, "dprawhit");
const auto & fitParams = hitResults->vectors();
//Getting number of hits in all Cryostats, TPC's, planes and wires before this plane
int FitParamsOffset = CountHits(evt, which, rawOpt->fCryostat, rawOpt->fTPC, plane);
.
.
}


int RecoBaseDrawer::CountHits(const art::Event&              evt,
                              const std::string&             which,
                              unsigned int                   cryostat,
                              unsigned int                   tpc,
                              unsigned int                   plane)
{
std::vector<const recob::Hit*> temp;
int NumberOfHitsBeforeThisPlane=0;
evt.getView(which, temp);   //temp.size() = total number of hits for this event (number of all hits in all Cryostats, TPC's, planes and wires)
for(size_t t = 0; t < temp.size(); ++t)
{
        if( temp[t]->WireID().Cryostat == cryostat && temp[t]->WireID().TPC == tpc && temp[t]->WireID().Plane == plane ) break;
                NumberOfHitsBeforeThisPlane++;
}
return NumberOfHitsBeforeThisPlane;
}
```

Summary and Outlook

- Changes work fine for dual phase and do not affect single phase

- Will not work for "mixed mode" in single phase (=deconvolution in induction planes + raw waveform fitting in collection plane)

→ address this problem later

- Will push changes to lareventdisplay repository if no objections